

## CLAIMS

- 1 1. An error correction code encoder for encoding data in accordance with one or more  
2 factors of a generator polynomial  $g(x) = g_1(x) * g_2(x)$ , the encoder including:
- 3 A. a first stage for selectively multiplying symbols by  $g_1(x)$  to produce a product  
4 or dividing the symbols by  $g_1(x)$  to produce one or both of a quotient  $q_1(x)$   
5 and a remainder  $r_1(x)$ ;
- 6 B. a second stage for dividing  $q_1(x)$  by the polynomial  $g_2(x)$  to produce a  
7 remainder  $r_2(x)$ ;
- 8 C. a controller for operating the first and second stages, the controller operating  
9 a. in a first mode to supply the data to the first stage, the associated  
10 quotient  $q_1(x)$  to the second stage, the associated remainder  $r_2(x)$   
11 produced by the second stage back to the first stage and control the  
12 first stage to produce the product  $r_2(x) * g_1(x)$ ;
- 13 b. in a second mode to by-pass the second stage; and  
14 c. in a third mode to pass the data to the second stage as the quotient  
15  $q_1(x)$ ; and
- 16 D. a processor for producing ECC symbols by manipulating the remainders and  
17 products produced by the first and second stages.
- 1 2. The encoder of claim 1 wherein the controller operating in the third mode passes the  
2 data through the first stage to supply the data to the second stage as the quotient  $q_1(x)$ .
- 1 3. The encoder of claim 1 wherein the second stage includes  
2 j stages that multiply the symbols by coefficients of degree-one factors of  $g_2(x)$ ;  
3 and  
4 a multiplexer that selectively operates a stage  $j-i$  as the last stage, where  $0 \leq i < j$ .
- 1 4. The encoder of claim 1 wherein the second stage encodes in accordance with  $g_2(x) =$   
2  $g_3(x) * g_4(x)$ , the second stage including:

3 a first sub-stage for selectively multiplying symbols by  $g_3(x)$  to produce a product  
4 or dividing the symbols by  $g_3(x)$  to produce one or both of a quotient  $q_3(x)$  and a  
5 remainder  $r_3(x)$ ;  
6 E. a second sub-stage for dividing  $q_3(x)$  by the polynomial  $g_4(x)$  to produce a  
7 remainder  $r_4(x)$ ;  
8 F. a controller for operating the first and second sub-stages, the controller  
9 operating  
10 in a first mode to supply the quotient  $q_1(x)$  to the first sub-stage, the  
11 associated quotient  $q_3(x)$  to the second stage, the associated remainder  
12  $r_4(x)$  produced by the second sub-stage back to the first sub-stage and  
13 control the first sub-stage to produce the product  $r_4(x)*g_3(x)$ ;  
14 in a second mode to by-pass the second sub-stage; and  
15 in a third mode to pass the quotient  $q_1(x)$  to the second sub-stage as the  
16 quotient  $q_3(x)$ ;  
17 wherein the second stage provides to the processor the remainders and products  
18 produced by the first and second sub-stages.

1 5. An error correction code encoder for encoding data in accordance with one or more  
2 factors of a generator polynomial  $g(x) = g_1(x)*g_2(x)$ , the encoder including:  
3 A. a first stage for selectively multiplying the symbols by  $g_1(x)$  to produce a  
4 product or dividing symbols by  $g_1(x)$  to produce one or both of a quotient  
5  $q_1(x)$  and a remainder  $r_1(x)$ ;  
6 B. a second stage for dividing  $q_1(x)$  by one or more factors of the polynomial  
7  $g_2(x)$  to produce a remainder  $r_2(x)$ ;  
8 C. a controller for operating the first and second stages, the controller operating  
9 a. in a first mode to supply the data to the first stage, the associated  
10 quotient  $q_1(x)$  to the second stage, the associated remainder  $r_2(x)$   
11 produced by the second stage back to the first stage and control the  
12 first stage to produce the product  $r_2(x)*g_1(x)$ ;  
13 b. in a second mode to by-pass the second stage; and

- 14 c. in a third mode to pass the data to the second stage as the quotient  
15  $q_1(x)$ ; and  
16 D. a processor for producing ECC symbols by manipulating the remainders and  
17 products produced by the first and second stages.

- 1 6. The encoder of claim 4 wherein the second stage includes  
2 j stages that multiply the symbols by coefficients of degree-one factors of  $g_2(x)$ ;  
3 and  
4 a multiplexer that selectively operates a stage  $j-i$  as the last stage, where  $0 \leq i < j$ .

- 1 7. A method for encoding k data symbols in accordance with one or more factors of a  
2 generator polynomial  $g(x) = g_1(x) * g_2(x) * \dots * g_i(x)$  of degree  $n-k$ , the method including:  
3 A. using one or more factors of  $g(x)$  as a selected polynomial  $p(x)$  of degree m,  
4 where  $1 \leq m \leq n-k$ ; *in step 10*  
5 B. dividing the data symbols by a first factor  $p_1(x)$  of  $p(x)$  to produce a remainder  
6  $r_1(x)$  and/or a quotient  $q_1(x)$ , the first factor having degree s;  
7 C. if  $p(x)$  has more factors dividing the quotient  $q_1(x)$  by a next factor  $p_i(x)$  of the  
8 polynomial  $p(x)$  to produce a remainder  $r_i(x)$ ;  
9 D. if  $p(x)$  has more factors dividing the quotient  $q_i(x)$  by a next factor  $p_{i+1}(x)$  to  
10 produce a remainder  $r_{i+1}(x)$  and/or a quotient  $q_{i+1}(x)$ ;  
11 E. repeating steps C and D for the remaining factors of  $p(x)$ ; and  
12 F. manipulating the remainders to produce redundancy symbols.

- 1 8. The method of claim 7 wherein the step of manipulating the remainders includes the  
2 steps of  
3 multiplying the respective remainders  $r_i$  by associated factors  $p_i(x)$ , for  $t =$   
4  $1, 2, \dots, i-1$ ;  
5 adding the results to  $r_1(x)$  to produce a remainder sum; and  
6 shifting the remainder sum by  $x^{n-s}$  to produce ECC symbols.

- 1 9. A method for encoding  $k$  data symbols in accordance with one or more factors of a  
2 generator polynomial  $g(x) = g_1(x) * g_2(x)$  of degree  $n-k$ , the method including:  
3 A. selecting  $g_1(x)$ ,  $g_2(x)$  or  $g_1(x) * g_2(x)$  as a polynomial  $p(x)$  of degree  $m$ , where 1  
4  $\leq m \leq n-k$ ;  
5 B. dividing the data symbols by a first factor  $p_1(x)$  of  $p(x)$  to produce a remainder  
6  $r_1(x)$  and/or a quotient  $q_1(x)$ , the first factor having degree  $s$ ;  
7 C. if  $p(x)$  has a second factor dividing the quotient  $q_1(x)$  by a next factor  $p_2(x)$  of  
8 the polynomial  $p(x)$  to produce a remainder  $r_2(x)$ ; and  
9 D. manipulating the remainders to produce redundancy symbols.

- 1 10. The method of claim 9 wherein the step of manipulating the remainders includes  
2 using  $r_1(x)$  as the ECC symbols.

- 1 11. The method of claim 10 wherein the step of manipulating the remainders includes the  
2 steps of  
3 multiplying  $r_2(x)$  by  $p_1(x)$  to produce a product,  
4 adding the product to  $r_1(x)$  and  
5 shifting the result by  $x^{n-s}$ .

- 1 12. A decoder for decoding a code word that is encoded in accordance with one or more  
2 factors of a generator polynomial  $g(x) = g_1(x) * g_2(x)$ , the decoder including:  
3 A. a first stage for selectively multiplying the symbols by  $g_1(x)$  or dividing  
4 symbols by  $g_1(x)$  to produce either a remainder  $r_1(x)$ , a quotient  $q_1(x)$  or both  
5 the remainder and the quotient;  
6 B. a second stage for dividing the quotient  $q_1(x)$  by the polynomial  $g_2(x)$  to  
7 produce a remainder  $r_2(x)$ ;  
8 C. a controller for operating the first and second stages, the controller operating  
9 a. in a first mode to supply the data to the first stage, the associated  
10 quotient  $q_1(x)$  to the second stage, the associated remainder  $r_2(x)$   
11 produced by the second stage back to the first stage and control the  
12 first stage to produce the product  $r_2(x) * g_1(x)$ ;

- 13                   b. in a second mode to by-pass the second stage; and
- 14                   c. in a third mode to pass the data to the second stage as the quotient
- 15                    $q_1(x)$ ; and
- 16       D. a processor for producing ECC symbols by manipulating the remainders and
- 17           products produced by the first and second stages, the processor comparing the
- 18           ECC symbols with the code word ECC symbols and, as necessary, producing
- 19           error syndromes and correcting errors in the data to produce error-free data.

1    13. A decoder for decoding code words encoded in accordance with one or more factors  
2    of a generator polynomial  $g(x) = g_1(x) * g_2(x)$ , the decoder including:

- 3           A. a first stage for selectively dividing symbols by  $g_1(x)$  to produce a quotient
- 4                $q_1(x)$  and/or a remainder  $r_1(x)$  or multiplying the symbols by  $g_1(x)$  to produce
- 5               a product;
- 6           B. a second stage for dividing  $q_1(x)$  by one or more factors of the polynomial
- 7                $g_2(x)$  to produce a remainder  $r_2(x)$  or producing error syndromes associated
- 8               with the one or more factors of  $g_2(x)$ ;
- 9           C. a controller for operating the first and second stages, the controller operating
  - 10               a. in a first mode to supply the data to the first stage, the associated
  - 11               quotient  $q_1(x)$  to the second stage, the associated remainder  $r_2(x)$
  - 12               produced by the second stage back to the first stage and control the
  - 13               first stage to produce the product  $r_2(x) * g_1(x)$ ;
  - 14               b. in a second mode to by-pass the second stage; and
  - 15               c. in a third mode to pass the data to the second stage as the quotient
  - 16                $q_1(x)$ ; and
  - 17               d. in a fourth mode to operate the second stage to produce error
  - 18               syndromes associated with the one or more factors of  $g_2(x)$ ; and
- 19       D. a first processor that produces ECC symbols by manipulating the remainders
- 20           and products produced by the first and second stages; and
- 21       E. a second processor that produces error syndromes associated with  $g_1(x)$  and
- 22           uses the error syndromes produced by the second stage to, as necessary,
- 23           correct errors in the data and produce error-free data.